

ATTACHMENT J.4.6

FINAL HAZARD ANALYSIS REPORT FOR OPERABLE UNIT 4

25-HS-0004, SEPTEMBER 1995

FINAL HAZARD ANALYSIS

REPORT FOR

OPERABLE UNIT 4

25-HS-0004

Prepared by the FHAR Team Consisting of

Robert Purcell, Chair, FERMCO Safety Analysis

William Tope, FERMCO CRU4 FSAR Coordinator

David Gooderum, FERMCO CRU4 Startup & Operations

Gregg Johnson, FERMCO Health and Safety

Victoria Werner, FERMCO Human Factors Safety

John Bootle, PARSONS Engineering

Mike Chrostowski, PARSONS Environmental Safety and Health

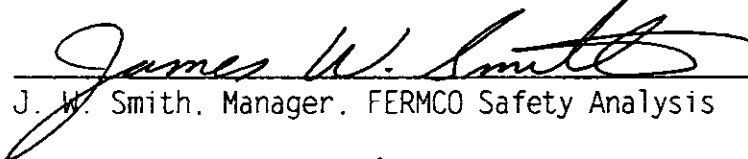
September 1995

Approval Page


FINAL HAZARD ANALYSIS
FOR OPERABLE UNIT 4



R. A. Purcell, Chair, FERMCO Safety Analysis Date 9/5/95



J. W. Smith, Manager, FERMCO Safety Analysis Date 9/12/95



M. C. Skriba, Manager, FERMCO CRU4 Date 120595

Final Hazard Analysis Report for Operable Unit 4

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SECTION 1

EXECUTIVE SUMMARY

The Final Hazard Analysis on this project was performed to identify standard hazards, safety-significant items, and risks requiring additional analysis. The Final Hazard Analysis uses a process that demonstrates that all Phase II project phases and processes have been analyzed for this identification. The methodology and findings are included in this report, the Final Hazard Analysis Report for OU4.

The result of this analysis is the identification of six safety-significant hazards. Moreover, engineered controls and administrative controls are identified that are used to mitigate these hazards. These requirements are being addressed prior to operation of Operable Unit 4 (OU4) and shall be included in the project Final Safety Analysis Report (FSAR) for OU4. The identified hazards together with the engineered and administrative controls are:

- 1) Explosion in the Furnace
- 2) External Radiation from Process Vessels
- 3) External Dose Hazard from the Vitrified Product
- 4) Personnel Falling into a Silo
- 5) Silo Containment Breached
- 6) Leak/Spill of Molten Glass or Heavy Metals from Furnace

The engineered and administrative controls required to mitigate the hazards are:

- 1) Emergency off-gas rupture disk
- 2) Shielding
- 3) Containment box under melter
- 4) Radiation Protection Program
- 5) Hazardous Material Protection Program
- 6) Silo Dome Load Limits
- 7) Rigging Plan
- 8) Fall Protection Program

Table ES-1 links the mitigators to the hazard. The purpose of the engineered and administrative controls is to mitigate the hazard risk either by reducing the consequence or the probability of occurrence. Each of these hazards and safety-significant controls and mitigators is fully discussed in the FSAR.

Table ES-1 - Hazards and Mitigators

Hazard Description	Hazard Type	Engineered Controls	Administrative Controls
Explosion in the Furnace	1	Emergency off-gas rupture disk	None
External radiation from Process Vessels	4	Shielding	Radiation Protection Program
External dose hazard from the vitrified product	4	Shielding	Radiation Protection Program
Personnel falling into a silo	4	None	Radiation Protection Program Hazardous Material Protection Program Silo Dome Load Limits Fall Protection Program
Silo Containment Breached	10	None	Silo Dome Load Limits Rigging Plan
Leak/Spill of Molten Glass or Heavy Metals from Furnace	10	Containment box under melter	None

Key for Hazard Types as Defined in Table ES-1

- 1 Fire/Explosion
- 4 Radioactive
- 10 Spill/Loss of Containment

SECTION 2

INTRODUCTION TO FINAL HAZARD ANALYSIS

As defined in the Integrated Hazard Analysis Plan that was transmitted to DOE (Reference 1), the purpose of the Final Hazards Analysis is to conduct follow-up, systematic hazard and qualitative accident analysis based on the results of the Preliminary Integrated Hazard Analysis for the CRU4 Pilot Plant (PHA) report (Reference 2) to ensure that the final design, construction, and operations incorporate appropriate protection for the general population, co-located workers, and facility workers (operators). This Final Hazards Analysis Report (FHAR) provides the hazard analysis required by DOE Order 5480.23 (Reference 3) for the facility Final Safety Analysis Report (FSAR). Follow-up actions identified in the PHA, such as performing a more detailed analysis or gathering more information where needed, have been incorporated. The scope of this FHAR includes the K-65 Silo 2, Silo 3, and Radon Treatment System (RTS) as they will exist during Phase II pilot plant operations. It also includes Phase II pilot plant operations.

Facilities such as the CRU4 Pilot Plant at this FSAR phase are in construction. Life cycles include project stages from Site Preparation, Construction, Operation, Maintenance/Surveillance, and Decommissioning and Decontamination (D&D).

2.1 Criteria

Criteria used in this analysis are:

1. Table 1 provides a risk matrix that defines safety significance. The criteria are consistent with DOE STD-3009-94 and recognize the importance of worker safety. The DOE Standard defines the matrix cells as "bins." Anticipated scenarios that result in multiple serious injuries to workers, as well as unlikely scenarios that result in worker fatalities, are considered safety significant.
2. Table 2 initially defines consequence class based on the defined consequences to specific populations. Table 2 was generated by the original PHA team to provide boundaries for specification of consequence classification and subsequently revised during further development of safety documents related to this project.
3. Standard or common industrial hazards identified in the hazard analysis are not subject to frequency/consequence binning. Standard or industrial hazards are those which are controlled or mitigated by application of OSHA standards.

Table 1 - Criteria for Safety Significance

Estimated Annual Probability of Occurrence (p)	Hazard Consequence		
	Low	Moderate	High
Anticipated $p \geq 10^{-2}$	4	7	9
Unlikely $10^{-2} \geq p > 10^{-4}$	2	5	8
Extremely Unlikely $10^{-4} \geq p > 10^{-6}$	1	3	6
Incredible $10^{-6} \geq p$			

- The areas bounded by the dark line indicate areas with safety significance.
- Binning (Numbers 1 through 9) is based on DOE-STD-3009-94.

Table 2 - Consequence Classification

	Worker Safety	Worker Radiation Exposure	Worker Chemical Exposure	Public Radiation Exposure	Public Chemical Exposure	Public Safety
High	Multiple Fatalities	> 250 Rem	ERPG-3	> 25 Rem	ERGP-2	Serious Injury
Moderate	1 Fatality or >5 Serious Injuries	> 5 but <250 Rem	ERPG-2	> 0.5 but < 25 Rem	ERPG-1	Minor Injury
Low	> 1 but <5 Serious Injuries	>0.5 but < 5 Rem	ERPG-1	> 0.01 but < 0.5 Rem	TLV-TWA	No Impact
Below Concern	Minor Injuries	<0.5 Rem	PEL-TWA	< 0.01 Rem and other legal limits on normal emissions	EPA and other legal limits on normal emissions	No Impact

NOTE: For the purposes of this chart a serious injury is defined as an injury that results in a worker being unable to continue his/her work on a normal basis (lost time).

SECTION 3

HAZARD ANALYSIS PROCESS

The team conducted the updated FHAR using a two-step process: 1) identification and 2) analysis.

The process started by listing the materials encountered in the OU4 operation. The material listing included the physical and chemical properties of these materials (Section 3.1). The team then performed an analysis of binary mixtures of the materials (Section 3.2 and Table 3).

A listing of the hazards that are encountered in any generalized process is proposed in Table 4. The team used available information on the existing OU4 facilities and vitrification processes to determine (Section 3.3) when the generalized hazards are encountered. A hazard matrix was prepared to link a potential hazard to a facility/activity (Table 5).

Finally, the identified hazards in Table 5 were sorted by hazard type and entered into an FHAR evaluation Table (Appendix A) along with possible causes and potential unmitigated consequences. After standard industrial hazards were screened out, the remaining hazards were assigned a frequency and consequence class, and the controls and mitigators for each hazard were identified. This information was then used to identify safety-significant design features that require special attention and/or additional analysis. The "Activity Numbers Associated with the Hazard" field of Appendix A provides a cross-reference to the specific hazard evaluated with a facility or activity as identified in Table 5.

3.1 Reactive Materials

The materials/compounds/mixtures used in OU4 operations are existing mixtures of compounds (silo contents, production residues), glass-making additives, cooling water, process additives, and effluent treatment chemicals.

3.2 Reactive Material Binary Matrix

The chemical and physical consequence of mixing any of these materials/compounds/mixtures is presented in Table 3, Reactive Material Binary Matrix. Special binary reactive hazards identified in this analysis are steam explosions when the hot glass traps small amounts of water or aqueous solutions, charcoal filter fires, and potential for burns/scalds if water is added to strong caustic (instead of the reverse). Table 3 does not address the probability of mixing occurring. The probability of the mixing and any controls/mitigators is evaluated in Appendix A.

3.3 Facility/Activity Hazard Identification

This analysis technique compares a facility or activity to a list of hazards. The product of this analysis is a matrix indicating the presence of hazards in a facility or activity. Matrix details are dependent on both the data available in the hazards listing and the facility/activity knowledge.

3.3.1 Hazards Listing

The generalized hazards for the existing OU4 facilities and operations are identified in Table 4. This list of hazard types was extracted from Guidelines for Hazard Evaluation Procedures (Reference 4). Each hazard is approached by considering whether this hazard can be encountered in an activity, a process step, and/or a facility. Where possible, it is denoted whether the hazard is acute or chronic.

3.3.2 Definition of Process, Facility, or Operation Stage

Life Cycle stages are Site Preparation, Construction, Operation, Maintenance/Surveillance, and Shutdown/Decommissioning and Demolition (D&D). Another Life Cycle stage in existing OU4 facilities is their present condition during OU4 vitrification pilot plant operation.

3.3.2.1 Pilot Plant

3.3.2.1.1 Pilot Plant Life Cycle (Excluding Operations)

Excluding operations, the Vitrification Pilot Plant Life Cycle activities are Site Preparation, Facility Construction, Silo 3 Preparation, Silo 2 Preparation, D&D, and Maintenance (Table 5, Activity Nos. 1 to 6).

3.3.2.1.2 Pilot Plant Operations

Vitrification Pilot Plant operations are based on the Process Block Flow Diagram (Figure 1):

Unit Operation	/Activity #
Silo 2 Hydraulic Material Removal	7 - 11
Silo 3 Pneumatic Material Removal	12 - 14
On-Site Transportation of Material	15 - 17
Silo 3 Material Transfer System	18
Slurry Tank	19

Unit Operation	/Activity #
Additives	20
Furnace	21
Product Forming	22
Product Handling	23
Furnace Area Storage	24 - 25
Off-Gas Treatment	26 - 32
Emergency Off-Gas	41 - 43
Recycle Water	45 - 48
Radon Sparging	49 - 51
Building Sump	52 - 53
Electrode Cooling Water	54 - 55
Process Cooling Water	56 - 58
Process Air	59 - 60
Standby Power	61 - 64
Sampling and Analysis	65 - 66

3.3.2.2 Existing OU4 Facility and Operation

The existing facilities associated with OU4 operations are the K-65 Silos, Silo 3, and the RTS. During the OU4 Phase II operation, the existing facility activity is the operation of the refurbished RTS. The activities are as follows:

Unit Operation	Activity
K-65 Silos	33
Silo 3	34
Existing RTS	35
Existing RTS Operation	36-40

3.4 Facility/Activity Hazard Evaluation

An evaluation is performed on any potential hazard identified in Section 3.3 (Facility/Activity Hazard Identification). The identified hazards consider the specific hazards identified in Section 3.1 (Reactive Materials) and Section 3.2 (Reactive Material Binary Matrix). Appendix A lists the results of the hazard evaluation.

Table 3 - Reactive Material Binary Matrix

1.	K-65 Residue	Mixture of metal oxides, many radioactive, and wet clays and silts. Layer of fine clay silt (bentonite) added in 1991 to the top of the silo residues to slow radon gas diffusion from radium decay in the residue. The residue is a stratified muck covered with a crusty surface. The bentonite is a foot thick (minimum) slurry seal that lies on top of the crust.										
2.	Silo 3 Residue	Calcined oxides of processed uranium ore. Physical properties of materials are dry and are fine particles with an angle of repose of 20 degrees. Consists of oxides and salts of process wastes containing radioactive material, and is not a major source of radon gas.										
3.	Water	Fluid used as solvent, cooling medium, and for hydraulic mining of the K-65 Silos.										
4.	Air	Working medium in the pneumatic removal from Silo 3 materials, operating slurry and water pumps.										
5.	Flocculent	A material that accelerates slurry settling. This material is organic with minor effects on skin upon direct contact.										
6.	Glass formers	Mixtures of light metal oxides added to the slurry; serves as a flux. Assists in dissolution of solids.										
7.	Activated Charcoal	Off-gas system adsorbent for radon. Radon-trapping properties poisoned by organics and water. Organics may be combustible.										
8.	Caustic	Used as off-gas chemical scrubbing agent. Material is hazardous.			C							
9.	CaCl ₂	Desiccant, used in the off-gas system (protects activated charcoal from moisture).										
10.	Glass Melt	A mixture of silo residues and glass formers in the molten state (thermal hazards, melt temp > 1100 °F).			A					B	A	
			1.	2.	3.	4.	5.	6.	7.	8.	9.	10.

Table 3 - Binary Reactive Material Matrix (Continued)

<u>Reactive Matrix</u>		
<u>Codes</u>		
A.	Steam Explosion	Mixture of glass melt and water or caustic/SDCD. Energetic consequence. Very hazardous local event.
B.	Charcoal Filter Fire	Glass melt ignites charcoal in charcoal traps. Radioactive material release
C.	Burns/Scalds	Adding small amounts of water to strong caustic or CaCl_2 (instead of the reverse). Local hazard
Note: This table does not address the probability of an event occurring. Contact between Silo 3 materials and air is removal process operation.		

Table 4 - Hazard Type and Criteria for the Hazard Type

Hazard Type #	Hazard Type	Criteria
1.	Fire/Explosion	Does the process/component present a fire/explosion hazard? (Acute Hazard)
2.	Caustic/Acidic	Does the process/component involve a caustic/acidic material? (Acute Hazard)
3.	Toxic	Does the process/component involve a toxic material? (Acute and/or Chronic Hazard)
4.	Radioactive	Does the process/component involve a radioactive material? (Chronic Hazard)
5.	Kinetic/Rotational	Does the process/component involve rotary or linear movement? (Acute Hazard)
6.	Potential/Elevation	Is the process/component elevated, or does it have suspended overhead components? (Acute Hazard)
7.	Electrical	Does the process/component use exposed electrical components? (Acute Hazard)
8.	Thermal/Freezing	Does the process/component involve high/low temperature? (Acute Hazard)
9.	Pressurized Fluids	Does the process/component involve the use of pressurized fluids? (Acute Hazard)
10.	Spill/Loss of Containment	Will breach of the process/component release contained hazardous materials? (Acute and/or Chronic Hazard)
11.	Confined Space	Does the process/component require entry into confined spaces? (Acute Hazard)
12.	Construction Safety	Does construction/maintenance of the process/component involve special hazards?
13.	Industrial Hygiene/Safety	Does the process/component present special Hygiene/Safety Hazards?
14.	Criticality	Does the process/component require special restrictions to reduce the nuclear criticality hazard?
15.	Other	Any additional process/component hazards (i.e. biohazards [BH], external events[EE])?

Table 5 - OU4 Hazard/Activity Matrix

Unit Operation	No.	Activity	Hazard Type Number														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Life Cycle of the Pilot Plant (excluding operation)	1	Site Preparation	X			X		X	X				X	X	N,H		BH
	2	Vitrification Facility Construction	X		X		X	X	X		X		X	X	N		BH
	3	Silo 3 Preparation (including connect piping)			X	X		X				X		X	N,H		BH
	4	K-65 Silo Preparation (including connect pump piping)	X		X	X		X				X		X	N,H		BH
	5	D&D	X		X	X		X	X			X	X	X	N,H, L		BH
	6	Maintenance	X	X	X	X	X	X	X	T	X	X	X	X	N,H, L		BH
Hydraulic Mining from K-65 Silo	7	Deleted During Review															
	8	Hydraulic Mining Operation			X	X	X	X	X		X	X			N,H		
	9	Thickener and Flocculent Operations			X	X	X	X	X	F	X	X					EE
	10	Use of Recycle Water During Mining			X	X				F	X	X					
	11	Repair of Bentonite after in situ Operation			X	X		X				X			N,H		
Pneumatic Removal from Silo 3	12	Deleted During Review															
	13	Pneumatic Removal Operation			X	X	X	X	X			X					
	14	Filter/ Receiver Operation			X	X	X		X			X					
On-Site	15	Disconnect from Silo 3			X	X		X				X					
Transportation of Material	16	Material Movement to Pilot Plant	X		X	X	X					X					EE
	17	Transfer to Surge Bin			X	X	X	X				X					

Table 5 - Pilot Plant Matrix (Continued)

Unit Operation	No.	Activity	Hazard Type Number														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Silo 3 Material Transfer	18	Silo 3 Material Feed to Slurry Tank			X	X	X	X				X					EE
Slurry Tank	19	Slurry Tank Operations			X	X				F		X					EE
Additives	20	Glass Making Additive Operations			X		X										
Furnace	21a	Level Control	X		X	X						X			H,L		
	21b	Temperature Control	X		X	X				T					H,L		
	21c	Pressure Control	X		X	X									H,L		
	21d	Electrode Replacement	X		X	X		X	X	T		X			N,H, L		
	21e	Bottom Drain	X		X	X				T		X			XN,H ,L		
	21f	Side Chamber Feed			X	X		X		T		X			N,H, L		
Product Forming	22a	Product Forming (Gob Cutter)			X	X	X	X	X	T		X			N,H, L		
Product Handling	23a	Product Cooling/Transport Conveyor	X		X	X	X	X		T		X			N,H, L		
	23b	Loadout Stations			X	X	X			T		X			N,H, L		

Table 5 - Pilot Plant Matrix (Continued)

Unit Operation	No.	Activity	Hazard Type Number														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Furnace Area Storage	24	Product Storage in Furnace Area			X	X				T		X			N,H, L		EE
	25	Prep for On-Site Shipping			X	X	X					X					EE
Pilot Plant Off-Gas System	26	Quench Tower Operation (Air side)				X				T		T			N,H		
	27	Scrubber Operation (Air side)			X	X						X			N,H		
	28	Desiccant Tower Operation			X	X		X				X			N		
	29	Charcoal Bed Operation	X		X	X						X			N,L		
	30	HEPA Filter Operation	X			X						X			N,L		
	31	Off-Gas Fan/Blower Operation					X								N,L		
	32	Exhaust Stack						X									
Existing Facilities	33	K-65 Silos			X	X		X				X					EE
	34	Silo 3			X	X		X				X					EE
	35	Existing RTS System	X		X	X						X					
Existing Facility Operation	36	Deleted During Review															
	37	RTS Piping to/from Silo				X						X					
	38	RTS Fan Operation				X	X					X					
	39	RTS Desiccant Tower Operation			X	X						X					
	40	RTS Charcoal Bed Operation	X		X	X						X					
Emergency Off-Gas	41	Automatic Valve Operation			X	X						X			N		
	42	HEPA Filter Operation	X		X	X									N,H		
	43	Blower Operation					X		X						N,H		

Table 5 - Pilot Plant Matrix (Continued)

Unit Operation	No.	Activity	Hazard Type Number														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	44	Rupture Disk Operation			X	X						X					
Recycle Water	45	Recycle Water Tank			X	X				F		X			N		EE
	46	Recycle Water Pump Operation (and Piping)			X	X	X			F	X	X			N		
	47	Quench Tower Pump Operation (and Piping)			X	X	X			F	X	X			N		
	48a	Cooling Water Heat Exchanger (Recycle Water Side)			X	X				F	X	X			N		
	48b	Waste Fillers			X	X				F	X	X			N		
Radon Removal	49	Sparge Tank			X	X				F		X			X		EE
	50	Sparge Tank Pump Operation (and Piping)			X	X				F	X	X			X		
	51	Electric Immersion Heater Operations	X		X	X				T		X			X		

Table 5 - Pilot Plant Matrix (Continued)

Unit Operation	No.	Activity	Hazard Type Number														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Building Sump	52	Building Sump			X	X				F		X					EE
	53	Building Sump Pump Operation (and Piping)			X	X				F	X				N		
Electrode Cooling Water	54	Cooling Water Pump Operation (and Piping and Tank)									X				N		
	55	Radiator Operation					X		X	T	X				N,H		
Process Cooling Water	56	Cooling Tower Operation		X			X				X				N		
	57	Cooling Tower Pump Operation (and Piping)									X				N		
	58	Heat Exchanger (Cooling Water Side)									X				N		
Process Air	59	Air Compressor Operation						X		T	X				N,H		
	60	Air Receiving Tank									X						
Standby Power	61	Diesel Engine Operation	X	X			X			T	X				N,H		
	62	Generator Operation	X				X		X						N,H		
	63	Uninterruptible Power Supply (UPS)	X	X					X	T					N,H, L		
	64	Day Tank (Diesel Fuel No. 2)	X		X						X	X			N,L		
Sampling and Analysis	65	Sampling Operation		X	X	X		X		T	X	X					
	66	Analysis In On-site Lab		X	X	X				T		X					
Notes	T - Thermal, F - Freezing, N - Noise, H - Heat Stress, L - Poor Lighting, BH - Biohazard, EE - External Event																

SECTION 4

IDENTIFIED SAFETY-SIGNIFICANT HAZARDS

The following hazards, as found by the three screening processes (Tables 3, 4, and 5) evaluated in the FHAR (Appendix A), were found to have unmitigated frequency and consequences to meet the criteria for safety significance per Table 1. These hazards and their controls (administrative and engineered) are listed in Table 6. Each of these hazards and safety-significant controls and mitigators is fully discussed in the FSAR.

Table 6 Identified Hazards and Mitigators

Hazard Description	Hazard Type	Engineered Controls	Administrative Controls
Explosion in the Furnace	1	Emergency off-gas rupture disk	None
External radiation from Process Vessels	4	Shielding	Radiation Protection Program
External dose hazard from the vitrified product	4	Shielding	Radiation Protection Program
Personnel falling into a silo	4	None	Radiation Protection Program Hazardous Material Protection Program Silo Dome Load Limits Fall Protection Program
Silo Containment Breached	10	None	Silo Dome Load Limits Rigging Plan
Leak/Spill of Molten Glass or Heavy Metals from Furnace	10	Containment box under melter	None

Key for Hazard Types as Defined in Table 6

- 1 Fire/Explosion
- 4 Radioactive
- 10 Spill/Loss of Containment

SECTION 5

REFERENCES

1. Letter, "Integrated Hazard Analysis Plan for the OU4 Pilot Plant," C:CRU4:94-0484, Wilf S. Pickles, FERMCO to Randi B. Allen, DOE-FN, dated August 2, 1994
2. Preliminary Integrated Hazard Analysis for the CRU4 Pilot Plant, July 20, 1994
3. DOE Order 5480.23, "Nuclear safety Analysis Reports," April 1992
4. Guidelines for Hazard Evaluation Procedures, 2nd Edition with Worked Examples, c1992, AIChE, TP155.5.G77

APPENDIX A

OU4 INTEGRATED HAZARDS ANALYSIS EVALUATION

OU4 Integrated Hazard Analysis Evaluation

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 1 Hazard Description: Flame ignition during welding Activities* Associated with the Hazard: 1, 2, 6						
Personnel injury/death due to explosion			N/A	A) Explosive/flammable gas present in area of welding operations B) Leak of explosive/flammable gas from welding equipment	1. FERMCO Hot Work Permit 2. Air Monitoring for explosive gasses. 3. Certified/experienced welders 4. Fire watch 5. Proper extinguishing agents present in immediate work area.	Standard Hazard
Equipment damage						
Project delay						
Hazard Type: 1 Hazard Description: Fire/Explosion initiation of Flammable Fluid Activities* Associated with the Hazard: 1, 2, 4, 5, 6, 16, 23a, 61, 62, 63, 64						
Possible serious personnel injury/death			N/A	A) Spill during local refueling with sparking B) Spill of stored fuels with sparking	1. Project operations require minimal flammable material 2. Task-specific procedures are approved and procedure training completed prior to work.	Standard Hazard
Possible equipment damage				C) Vehicle Fire D) Motor Fire	1. A fire protection program is in place prior to work initiation 2. Design includes a fire protection system including portable fire extinguishers and fire hydrants on either side of the plant. 3. The FEMP 24-hour Emergency Response Team (ERT) is trained on the project requirements and the project requirements sent to the Emergency Preparedness Team prior to work initiation 4. Task-specific procedures are approved and procedure training completed prior to work.	
Loss of material and equipment						
Local fire						
Hazard Type: 1 Hazard Description: Hydrogen Gas Explosion Activities* Associated with the Hazard: 36						
None	Moderate	Incredible	0	Buildup of H ₂ gas as a result of water decomposition and ignition by lightning or ungrounded equipment	Not a credible scenario since the hydrogen content of the silo gas has been measured at less than 0.1 percent which is less than the Lower Explosive Limit of H ₂ of 4 percent.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: I Hazard Description: RTS Charcoal Fire Activities* Associated with the Hazard: 35, 40						
Fire and rupture of the canisters causes large radon and radon daughter release	Low	Unlikely	2	A) Electrical initiator B) Organics buildup in charcoal	A fire protection program is in place.	
Hazard Type: I Hazard Description: Explosion in Furnace Activities* Associated with the Hazard: 21						
Glass lava spills out of furnace causing schedule delay Failure of adjacent equipment, piping, or support structure Possible death/serious injury to on-site personnel Spread of contamination	Moderate	Unlikely	5	A) Overpressurization due to steam buildup (exceeding off-gas system design basis) B) Operator error due to lack of training	1. Design includes engineered overpressurization protection 1. Task-specific procedures are approved and procedure training completed prior to work with furnace.	WSS HAZOP of furnace and emergency off-gas systems was performed to analyze and specify SSC's for these systems
Hazard Type: I Hazard Description: Off-Gas Charcoal Canisters/HEPA Filters Catch Fire Due to Excessive Temperature Activities* Associated with the Hazard: 29, 30, 42						
Fire and rupture of the canisters causes large radon release	Low	Unlikely	2	A) Off-gas temperature which enters the charcoal canisters or HEPA filters is above the ignition temperature of the charcoal due to quench tower failure (350-450 degrees C)	1. Project procedures include a fire protection program 2. Off-gas system includes two separate temperature indicating recorders that will alarm on high temperature	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 2 Hazard Description: Caustic solutions Activities* Associated with the Hazard: 6, 56, 61, 63, 65, 66						
Chemical Burns	Low	Unlikely	2	Exposure during startup and maintenance	1. Hazardous chemical work permits are issued 2. Emergency Showers are available prior to start of work 3. Task-specific procedures are approved and procedure training completed prior to work.	
Hazard Type: 3 Hazard Description: Exposure to fumes Activities* Associated with the Hazard: 2, 3, 4, 5, 6						
Possible serious personnel injury/death			N/A	A) Painting	1. General Work Permits are issued 2. Hazardous Chemical Work Permits are issued 3. Proper ventilation equipment are provided, if needed 4. FERMCO reviews of MSDS for used materials 5. Respirator is used, if required by MSDS 6. Respirator training and fit test (including annual refresher)	Standard Hazard
Hazard Type: 3 Hazard Description: Airborne suspensions of flocculent, CaCl₂, glass making additives, and bentonite Activities* Associated with the Hazard: 9, 11, 20, 28						
Personnel inhalation of suspensions	Below Concern	Anticipated	0	Standard pouring, dumping, shredding, and size reduction.	1. All listed materials have a low toxicity 2. Hazardous Chemical Work Permits are issued	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 3 Hazard Description: Exposure to Toxic Materials Activities* Associated with the Hazard: All except 1, 26, 30, 31, 32, 37, 38, 43, and 54 through 63						
Reportable personal contamination event	Below Concern	Unlikely	0	A) Operations	1. Process vessels and piping provide containment of toxic materials. 2. Off-gas system maintains air leakage into the furnace from the Furnace Room.	
				B) Spills/Leaks C) Loss of furnace off-gas	1. Design includes secondary container 2. Design includes emergency off-gas system	
Hazard Type: 4 Hazard Description: Work conducted in the Construction Zone, which is also a controlled area, without minimum requirements Activities* Associated with the Hazard: 1, 2, 3, 4, 5						
Possible serious personnel injury/death	Moderate	Extremely Unlikely	3	A) Inadequate personnel protective equipment B) Human error in following procedures C) Training inadequate	1. Requirements for hard hat, safety glasses with rigid side shield, steel-toed shoes 2. Construction rules/regulations, GET & refresher training - (all personnel, supervisors have OSHA 500 training) 3. All personnel who are to perform work in the construction zone are orientated to the: a. CRU4 General H&SP b. Job hazard analysis c. SPR awareness d. Health and Safety Requirements Matrix e. General Work Permit requirements	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: Violation of CERCLA Site-Controlled Area minimum requirements Activities* Associated with the Hazard: 1, 5, 8, 9, 10, 19, 28						
Reportable personal contamination event with potential for increased radiation exposure to the contaminated worker	Low	Unlikely	2	A) Human error in following procedures B) Training inadequate	1. Site Worker and Refresher Training 2. Site Specific Orientation Training 3. Minimum Rad I Training 4. Visitors are escorted by personnel with proper training 5. Personnel, equipment and material monitoring are required to exit the controlled area	
				C) Inadequate personnel protective equipment	1. Requirements for dosimeter (TLD) 2. Requirements for safety glasses with rigid side shields 3. Initial FERMCO or approved physical 4. Initial, annual and termination - In Vivo Testing	
Hazard Type: 4 Hazard Description: Radioactively Contaminated Dust Released to the Air from Preparation Activities Activities* Associated with the Hazard: 1, 3, 4						
Personnel exposure to contaminated dust	Low	Unlikely	2	A) Excavation and handling of contaminated soil	1. Design includes an dust suppression system 2. Radiation Work Permit are issued to ensure proper use of personal protective equipment (PPE) to prevent personnel contamination and exposure 3. Supervisor ensures prior process knowledge is used to identify potential hot spots	
Hazard Type: 4 Hazard Description: Direct contact with radioactive materials on skin, personal, or company issued "clean" clothing Activities* Associated with the Hazard: All except 2, 20, 31, 32, 43, 52, and 54 through 66						
Reportable personal contamination event with potential for increased radiation exposure to the contaminated worker	Low	Unlikely	2	A) Improper use of anti-Cs for intended scope of work B) In plan for radiological work task. C) Anti-C failure	1. Proper work planning that identifies the intended scope of work. 2. Issuance of FERMCO Radiation Work Permit identifies proper anti-C requirements for intended scope of work. 3. Pre-job brief with workers on work permit that ensures worker understanding of permit requirements for intended scope of work.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: Internal Radiation Exposure to the Worker from Silo Material during Removal Activities* Associated with the Hazard: 3, 4, 5, 6, 11, 13, 15, 17, 18						
Potential to exceed site dose limits resulting in facility shutdown, personnel injury	Below Concern	Anticipated	0	A) Inhalation /ingestion of radionuclide bearing dust residues if silo material exposed to atmosphere	1. Bag-in/bag-out procedures are in place. 2. Radiation Work Permit are issued to ensure proper usage of PPE 3. Task-specific procedures are approved and procedure training completed prior to work. 4. Design includes contaminated dust control during removal of Silo 3 material	
				B) Radiation Work Permit (RWP) is not updated as work progresses to reflect new conditions		
Hazard Type: 4 Hazard Description: External Radiation Exposure to the Worker from Silo Material during Removal Activities* Associated with the Hazard: 3, 4, 5, 6, 8, 11, 13, 15, 17, 33, 34						
Potential to exceed site dose limits resulting in facility shutdown, personnel injury	Below Concern	Anticipated	0	A) Presence of higher-than-expected penetrating radiation	1. Design applies As Low As Reasonably Achievable (ALARA) principles 2. Radiation Work Permit are issued to ensure proper usage of PPE	
				B) High level of radon, radium daughter, or thorium products in K-65 material leading to greater than anticipated dose rates		
				C) Radon daughters build up in head space of silo higher than expected	1. Radon Treatment System available, if necessary, to reduce radon concentration in the silo headspace to allow personnel access to the silo dome	
				D) Failure of protective clothing leads to excessive skin dose due to in training	1. Task-specific (including emergency) procedures are approved and procedure training completed prior to work. 2. Radiation Work Permit issued to ensure proper usage of PPE	
				E) RWP is not updated as work progresses to reflect new conditions		

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: Operational Releases of Radioactively Contaminated Dust, K-65 Decant Sump Liquid, or Radon in Excess of Allowed Limits Activities* Associated with the Hazard: 1, 2, 4, 8, 9, 10, 13, 15, 18, 19, 21, 29, 33, 37						
Adverse environmental impact or release exceeding standard	Below Concern	Anticipated	0	A) Work in the area disturbs excessive amounts of contaminated material B) Excavation of contaminated soil C) Handling of contaminated soil	1. Design includes contaminated dust control 2. RWP is issued for working in potentially contaminated soil. RWP updated as work progresses to identify contamination areas	
				D) Failure of radon collection systems	1. Design includes stack effluent monitoring system for radon 2. Sampling of radon sparge tank prior to release building sump is performed 3. Maintenance and inspection of filtration equipment is performed per vendor requirements	
				E) The decant tank overflows	1. During silo material removal, operations will monitor and drain the decant tank, as necessary	
Hazard Type: 4 Hazard Description: Personnel Falling into Silo Activities* Associated with the Hazard: 3, 4, 6, 11, 13, 15						
External and possible internal contamination Possible serious personnel injury/death	Moderate	Unlikely	5	A) Human error while repositioning the removal equipment and associated supports B) Excessive loads on the dome cause collapse.	1. Design for silo material removal includes minimal access to the silo dome 2. Task-specific procedures are approved and procedure training completed prior to work. 3. General work permit are issued specifying required PPE, including fall protection 4. Load limits on the dome have been established and are implemented in any activity requiring access to the silo domes	WSS Structural Dome Limit has been established
Hazard Type: 4 Hazard Description: Contamination of Heavy Machinery or Equipment Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6, 16, 25						

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Possible exposure to personnel Monetary loss	Below Concern	Anticipated	0	A) Contamination through routine use B) Personnel contamination transfers to equipment C) Material handling accident transfers contamination to equipment	1. Procedures are in place to minimize the transfer of contamination to equipment 2. decontamination procedures are in place prior to work initiation 3. Facility Owner shall ensure that bag-in/bag-out procedures are properly applied 4. Successful completion of training and qualification on material handling and decontamination procedures are completed prior to work	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: External Radiation from Process Vessels and Piping Activities* Associated with the Hazard: 9, 18, 19, 21, 29, 33, 65						
Exceeding Personnel Dose Limits	Low	Anticipated	4	A) Contact dose rates in excess of 500 mrem/hr (unshielded) from K-65 material expected	1. VPP Shielding designed to maintain dose rates below 2 mrem/hr in intermittent use areas and 0.25 mrem/hr in continuous use areas. 2. Radiation Work Permit issued to ensure proper usage of PPE	WSS
				B) Higher than expected radium source term from K-65 residues	1. Source term used in shielding based on 95th confidence limit on mean of samples taken from silos.	
				C) Process related abnormal operations leads to greater than expected quantities of K-65 material in process vessels	1. Design applies As Low As Reasonably Achievable (ALARA) principles. Shielding estimated assuming process vessels were completely full of K-65 material at 55 percent solids in thickener, 80 percent solids in slurry tanks, and 100 percent solids in furnace.	
Hazard Type: 4 Hazard Description: External Radiation from Samples Activities Associated: 66						
Exceeding Personnel Dose Limits	Below Concern	Anticipated	0	A) Samples contain radium-bearing materials	1. Radiation work permit issued to ensure proper usage of PPE 2. Fume Hood Operation (for potential radon concerns)	
Hazard Type: 4 Hazard Description: External Radiation from Radon-Laden Water Activities: 45, 46, 47, 48, 49, 50						
Exceeding Personnel Dose Limits	Below Concern	Anticipated	0	A) Concentrations may reach 1.2E8 pCi/l of radon in recycle water	1. Radiation Work Permit issued to ensure proper usage of PPE 2. Tanks and sump are vented to off-gas system to eliminate radon buildup in headspace	Thickener is largest source of radon in recycle water system
Hazard Type: 4 Hazard Description: External Radiation from RTS Process Vessel Activities: 39, 40						
Exceeding Personnel Dose Limits	Low	Unlikely	2	A) Radon buildup on tower and beds during operation of RTS	1. Tower and beds are shielded 2. RTS buildup is in remote location with respect to VPP 3. Radiation Work Permit issued to ensure proper usage of PPE	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: External Dose Hazard from the vitrified product Activities* Associated with the Hazard: 22, 23, 24, 25						
Difficulty in handling material causes schedule delay Possible exposure to personnel	Low	Anticipated	4	A) Contact dose rates in excess of 500 mrem/hr (unshielded) from K-65 material	1. ALARA principles are followed and a Radiation Work Permit issued to ensure proper usage of PPE 2. Gem Transfer containers designed with shielding to reduce contact dose rate below 50 mrem/hour.	WSS
Hazard Type: 4 Hazard Description: High Radon Emanation from the Product Activities* Associated with the Hazard: 22, 23, 24, 25						
Difficulty in storage and handling of the glass causes schedule delay Possible exposure to personnel	Low	Unlikely	2	A) Failure of the glass matrix to contain radon	1. Supervisor will ensure that radon flux is measured and surface contamination is checked prior to transport to the interim storage facility	
Hazard Type: 4 Hazard Description: High Radon Levels from Process Vessels and Piping Activities* Associated with the Hazard: 9, 19, 29, 65						
Internal exposure hazard to personnel working in the area	Below Concern	Anticipated	0	A) High radium content in the process material	1. Design includes process vessel headspace vents to the off-gas system	
				B) Loss of off-gas system	1. Design includes high airborne contamination alarms near thickener, slurry tanks, and carbon beds 2. Thickener, slurry tanks, and carbon beds are isolated by shielding from workers during operation	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 4 Hazard Description: High Radon Levels from Furnace Activities* Associated with the Hazard: 21						
Internal exposure hazard to personnel working in the area	Below Concern	Anticipated	0	A) Loss of off-gas system	1. Design includes emergency off-gas system for pressure control 2. Design includes airborne contamination alarms near furnace 3. Evacuation procedures are approved and procedure training completed prior to working near furnace	
Hazard Type: 5 Hazard Description: Kinetic/Rotating Equipment Activities* Associated with the Hazard: 2, 6, 8, 9, 13, 14, 16, 18, 19, 20, 22, 23, 25, 31, 38, 43, 56, 61, 62						
Possible personnel injury/death	Moderate	Extremely Unlikely	3	A) Human Error	1. Task-specific procedures are approved and procedure training completed prior to work.	
				B) Inappropriate Safety Devices	1. Project Engineer shall assure that all safety devices are properly installed	
Hazard Type: 6 Hazard Description: Crane accidents, employees struck by falling objects Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6, 15, 17						
Possible serious personnel injury/death			N/A	A) Human error in following procedures B) Training inadequate C) Inadequate personnel protective equipment	1. Competent operator (certification per specifications) 2. General work permit issued to ensure use of proper PPE	Standard Hazard
Hazard Type: 6 Hazard Description: Falls from elevated surfaces Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6, 8, 9, 11, 13, 14, 15, 18, 19, 21d, 21f, 22, 28, 32, 33, 34						
Possible serious personnel injury/death			N/A	A) Human error in following procedures B) Training inadequate C) Inadequate personnel protective equipment	1. Requirements for a safety harness and lifeline (retrieval system as required by FERMCO evaluation) 2. Fall Protection Plan is approved prior to work 3. Fall protection training is completed prior to work	Standard Hazard

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 6 Hazard Description: Falls from scaffold/ladder Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6						
Possible serious personnel injury/death			N/A	A) Human error in following procedures B) Training inadequate C) Inadequate personnel protective equipment	1. Fall protection plan is approved prior to work 2. Training in scaffold erection, use, and dismantling is completed 3. Training in proper use of ladders is completed	Standard Hazard
Hazard Type: 7 Hazard Description: Electrical Shock Hazard Activities* Associated with the Hazard: 1, 2, 5, 6, 8, 9, 13, 14, 21d, 22, 62, 63						
Possible serious personnel injury/death			N/A	A) Shorts in electrical cables	1. Supervisor shall ensure proper review of all electrical interfaces prior to implementation 2. Design includes Ground Fault Interrupter (GFI) equipment	Standard Hazard
Impact on site safety function				B) Overhead lines in work area resulting in construction equipment accident C) Underground line in area not known	1. Supervisor shall ensure proper review of all electrical interfaces prior to implementation 2. Construction Engineer shall ensure that Construction Environmental Health and Safety Work Survey was performed.	
Loss of power for production, schedule impact				D) Lock and tag failures or procedures not followed E) Training inadequate F) Inadequate PPE	1. Supervisor shall ensure proper review of all electrical interfaces prior to implementation 2. Facility Owner shall ensure the proper implementation of energy control lock and tag procedure	
Local fire				G) Electrical fire	1. Design includes a process shutdown to safe condition upon electrical failure	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 7 Hazard Description: Loss of Primary Electrical Distribution Power Activities* Associated with the Hazard: 8, 9, 13, 21						
Loss of electrically-operated equipment and instrumentation Equipment damage causing monetary loss Possible personnel injury	Below Concern	Unlikely	0	A) Equipment failure	1. Design includes backup power for critical functions 2. Design includes redundant power supplies for critical systems 3. Facility Owner shall ensure routine preventive maintenance	
				B) Human error	1. Supervisor shall ensure operators are trained and qualified on equipment operation and proper shutdown procedures	
				C) Natural catastrophe	1. Design includes backup power for critical functions 2. Design includes redundant power supplies for critical systems	
Hazard Type: 8 Hazard Description: Equipment Failure Due to Cold Weather Activities* Associated with the Hazard: 9, 10, 19, 45, 46, 47, 48, 49, 50, 52, 53, 60a						
Monetary loss due to equipment damage	Below Concern	Unlikely	0	A) Inadequate or failed freeze protection.	1. Design meets the cold protection provisions in DOE Order 6430.1A.	
Hazard Type: 8 Hazard Description: Thermal energy (high temperature) Activities* Associated with the Hazard: 6, 21b, 21d, 21e, 21f, 22, 23, 24, 26, 26a, 51, 55, 59, 61, 63, 65, 66						
Equipment and structure damage Burns or death to workers Ignition of combustible material nearby	Low	Unlikely	2	A) Insulation failure B) Lack of insulation C) Loss of cooling water	1. Design includes a fire protection system 2. Project procedures include a fire protection program 3. Hazardous Work Permits are issued to ensure PPE is used during work 4. Design includes temperature controls to idle or shut down the furnace 5. Furnace is surrounded by a metal cage to minimize contact with furnace.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 9 Hazard Description: Pressurized Vessels or Piping Failure Activities* Associated with the Hazard: 2, 6, 8, 9, 10, 46, 47, 48, 50, 53, 54, 55, 56, 57, 58, 59, 60, 60a, 61, 64, 65						
Loss of primary air supply			n/a	A) Weld/Seam Failure	1. Construction Engineer will ensure pre-operational testing. 2. Secondary Air Supply in place for critical functions. 3. Cooling water backup in place for critical functions	Standard Hazard
Loss of cooling water				B) Tank overpressurized	1. Pressure Relief Valve in place to relieve pressure in air system. 2. Supervisor will ensure successful completion of training and qualifications on system operation. 3. Cooling water backup in place for critical functions.	
Loss of recycle water						
Hazard Type: 10 Hazard Description: Silo (1, 2, or 3) Containment Breached Activities* Associated with the Hazard: 3, 4, 8, 11, 13, 15, 33, 34						
Possible serious personnel injury/death	Moderate	Unlikely	5	A) Rigging failure	1. Supervisor shall ensure proper use of the rigging plan 2. Supervisor shall ensure successful completion of training and qualification on heavy equipment use	WSS Structural Dome Limit has been established
Equipment damage/loss				B) Excessive loads on the dome cause collapse	3. Load limits on the dome have been established and are implemented in any activity requiring access to the silo domes	
Spread of airborne radioactive and hazardous contamination						
Internal/external exposure						
Loss of containment						

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 10 Hazard Description: Hazardous Material Release from Day Tank Activities* Associated with the Hazard: 64						
Environmental Release	Below Concern	Unlikely	0	A) Weld failure B) Material defect		
Hazard Type: 10 Hazard Description: Loss of Containment (Radon Treatment System) Activities* Associated with the Hazard: 26, 27, 28, 29, 30, 35, 37, 38, 39, 40, 49, 50						
Release of silo headspace gas recycle water, or furnace gas which contains radon Possible personnel injury Equipment damage causing monetary loss	Low	Unlikely	2	A) Weld or seam failure B) Material defect	1. QA/QC Engineer will ensure inspection of all welds 2. Construction Engineer will ensure pre-operational testing 3. Supervisor will ensure successful completion of training and qualification on system operation	
Hazard Type: 10 Hazard Description: Loss of Containment (Process Building) Activities* Associated with the Hazard: 23b, 24, 25						
Release of radium-bearing residues and dust Potential internal exposure	Below Concern	Unlikely	0	A) Forklift accident with vitrified product	1. Supervisor shall ensure successful completion of training and qualification for forklift operators 2. Radiation work permit will ensure proper usage of PPE during forklift operations.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 10 Hazard Description: Leak or Spill of Molten Glass or Heavy Metals from Furnace Activities* Associated with the Hazard: 21a, 21e						
Fire due to molten glass release Potential worker death/serious injury	Moderate	Unlikely	5	A) Loss of containment due to material defect B) Loss of containment due to worker error during installation	1. Design includes containment for furnace melt 2. Construction Acceptance Testing (CAT) performed prior to furnace startup	WSS Lessons learned from the MAWS project incorporated
				C) Loss of containment due to worker error from lack of training on system operation	1. Successful completion of operator training and qualification on the vitrification system operation will occur prior to working with furnace 2. Design includes containment for furnace melt	
				D) Loss of containment due to fire in furnace area	1. Facility Owner shall ensure that the work area minimizes the storage of combustible materials in the vitrified area 2. Design includes containment for furnace melt	
Hazard Type: 10 Hazard Description: Spills/release from thickener, Silo 3 surge bin, slurry tanks and transfer piping Activities* Associated with the Hazard: 9, 13, 14, 15, 16, 17, 18, 19						
Personnel injury Exposure to airborne radioactive and hazardous material to the public and workers	Low	Unlikely	2	A) Material defect B) Weld failure or seam failure C) Operator error D) Forklift accident	1. Secondary containment for process vessels is used to contain the release of material from spreading to other areas 2. Procedures are in place to minimize the transfer of contamination to equipment prior to starting work 3. Successful completion of training and qualification on material handling and decontamination procedures will occur prior to starting work with radioactive material	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 10 Hazard Description: Slurry Line from the Silos (1 or 2) Fails Activities* Associated with the Hazard: 8						
Release of slurry with K-65 residues causing spread of contamination	Low	Unlikely	2	A) Material defect B) Weld or seam failure	1. Design includes use of double wall pipe in outdoor areas and an Leak Detection System 2. Construction Engineer shall ensure pre-operational testing of slurry line 3. QA/QC Engineer shall ensure inspection of all welds	
Possible personnel exposure				C) Slurry line overpressurized	1. Design includes overpressurization protection 2. Construction Engineer shall ensure pre-operational testing of slurry line	
Possible equipment damage				D) Freeze/thaw action on slurry line	1. Design includes freeze protection for the slurry line	
				E) Vehicle accident pulls slurry line from silo F) Crane accident pulls slurry line from silo	1. Design locates the contaminated pipes in controlled areas 2. Supervisor shall ensure successful completion of training and qualification on vehicle operations, crane operation, and process operation for workers conducting those activities	
Hazard Type: 10 Hazard Description: Loss of Containment on High-Pressure Water Line Activities* Associated with the Hazard: 10						
Release of water which contains radionuclides	Below Concern	Unlikely	0	A) Overpressurization of line	1. Design locates contaminated pipes in controlled areas 2. Design includes overpressure protection 3. Design includes double walled pipe where appropriate 4. Design includes a Leak Detection System 5. Supervisor shall ensure successful completion of training and qualification on system operation	
Possible personnel injury				B) Weld or seam failure C) Material defect	1. QA/QC Engineer shall ensure inspection of all welds 2. Construction Engineer shall ensure pre-operational testing 3. Design includes double walled pipe where appropriate 4. Design includes a Leak Detection System 5. Design locates contaminated pipes in controlled areas	
Equipment damage causing monetary loss						

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 11 Hazard Description: Oxygen deficiencies due to confined space Activities* Associated with the Hazard: 1, 2, 5, 6						
Possible serious personnel injury/death			N/A	A) Human error in following procedures B) Training inadequate C) Inadequate personnel protective equipment	1. Continuous air monitoring is required in confined spaces 2. Safety harness and lifeline 3. Fall protection requirements 4. Entrant/attendant confined space training for permit required confined spaces 5. FERMCO Confined Space Permit requirements 6. Requirement for standby person for confined space 7. Requirement for ventilation	Standard Hazard
Hazard Type: 12 Hazard Description: Personnel Injury - Construction Related (Industrial) Activities* Associated with the Hazard: 1, 3, 4, 5, 6						
Possible serious personnel injury/death			N/A	A) Improper use of electrical supply, equipment, safety devices due to human error during construction B) Equipment energized during installation/ testing activities	1. Workers will receive general site worker training in addition to task specific training 2. Procedures are approved prior to work initiation	Standard Hazard
				C) Slip, trip and fall accidents D) Vehicle impact E) Eye injury F) Ear injury - excessive noise	1. Workers will receive general site worker training in addition to task-specific training	
				G) Material handling equipment is less-than-adequate	1. QA/QC Engineer shall ensure equipment inspection and testing prior to work initiation	
				H) Trench or excavation failure	1. Procedures for Excavation Penetration Permits and Facility Outage Permits are issued 2. Construction Engineer shall ensure the proper use of trench boxes, shoring, sloping, etc.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 12 Hazard Description: Hoisting and Rigging Failure Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6						
Possible serious personnel injury/death			N/A	A) Equipment failure B) Lack of maintenance of lifting equipment	1. Project Engineer will ensure equipment maintenance was completed prior to initiation of work	Standard Hazard
Equipment failure/damage				C) Operator error due to inadequate training D) Inadequate rigging design	1. Project Engineer shall ensure that the procedures are approved prior to work initiation 2. Completion of training and qualification on hoisting and rigging will occur prior to initiation of work 3. A complete sitewide hoisting and rigging plan (SSOP) is available prior to initiation of work	
Possible release of radioactive or hazardous contaminants						
Hazard Type: 13 Hazard Description: Noise - ear injury Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6, 8, 11, 21d, 21e, 21f, 22, 23, 24, 26, 27, 28, 29, 30, 31, 32, 41, 42, 43, 45, 46, 47, 48, 49, 50, 51, 53, 54, 55, 56, 57, 59, 61, 62, 63, 64						
Possible serious personnel injury			N/A	A) Human error in following procedures B) Training inadequate C) Inadequate personnel protective equipment	1. Hearing protection is provided for employees exposed to ≥ 85 dBA 8 hr. TWA 2. Medical monitoring is established for employees exposed to ≥ 85 dBA 8 hr. TWA	Standard Hazard
Hazard Type: 13 Hazard Description: Heat Stress Activities* Associated with the Hazard: 1, 3, 4, 5, 6, 8, 11, 21d, 21e, 21f, 22, 23, 24, 26, 27, 42, 43, 51, 55, 58, 59, 61, 62, 63						
Personal injury			N/A	A) Elevated worker temperatures from working inadequate Personnel Protective Equipment (PPE) B) Inadequate rest periods C) Worker failure to recognize symptoms of heat distress	1. Hazardous Work Permits will establish rest periods, cooling appurtenances, and use of the buddy system	Standard Hazard

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 13 Hazard Description: General Lighting Failure/Poor Lighting Activities* Associated with the Hazard: 5, 6, 21, 22, 23, 24, 29, 30, 31, 63, 64						
Personal Injury	Below Concern	Anticipated	0	A) Inadequate lighting design B) Power failure C) Lighting fixture failure	1. Emergency lighting is supplied where appropriate	Standard Hazard
Hazard Type: 15 Hazard Description: Contact with Biological Pathogens (Bugs, Snakes, and Poison Ivy) Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6						
Possible personnel illness/death			N/A	A) Inadequate personnel protective equipment	1. Construction Engineer shall ensure PPE is issued.	Standard Hazard
Hazard Type: 15 Hazard Description: Damage to the Furnace Due to Loss of Power Activities* Associated with the Hazard: 21b						
Molten glass would solidify in place possibly causing irreparable damage to the melter/furnace Adverse impact to project schedule	Below Concern	Anticipated	0	A) Loss of electricity to the melter	1. Design includes insulation to maintain melt for approximately 8 hours. 2. Design includes bottom drain to empty furnace contents	
Hazard Type: 15 Hazard Description: Vehicle Traffic Incident Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6, 16, 25						
Possible serious personnel injury/death Equipment damage Possible release of radioactive or hazardous contaminants			N/A	A) Poor traffic patterns used by operations B) Operator error	1. Supervisor shall ensure successful completion of qualification training for vehicle operators 2. Task-specific procedures are approved prior to work initiation 3. The project design restricts traffic in controlled areas 4. Facility Owner shall ensure that the project design includes necessary traffic barriers and controls	Standard Hazard

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 15 Hazard Description: Labor Dispute Activities* Associated with the Hazard: 1, 2, 3, 4, 5, 6						
Unsafe operating conditions could result in possible personnel injury Unsafe operating conditions could result in possible equipment damage			N/A	A) Failure of management and union to agree B) Improper industrial relations	1. Industrial Relations Representative shall ensure that formal industrial relations policies are followed 2. Trades Supervisor shall ensure that formal industrial relations policies are followed	Standard Hazard
Hazard Type: 15 Hazard Description: Loss of containment due to airplane Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
None		Incredible	0	A) Aircraft crash	Not a credible scenario since the nearest airport is 4.7 miles away and not considered a reasonable concern. The probability of an airplane crash at the FEMP is less than 10 ⁻⁶ .	
Hazard Type: 15 Hazard Description: Flood Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
None		Incredible	0	A) Large Dam break or overflow	Not a credible scenario since there are no dams immediately upstream of facility.	
Hazard Type: 15 Hazard Description: Loss of containment due to external missile Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
None		Incredible	0	A) Rail car accident/explosion	Not a credible scenario since no railroad tracks are in the immediate vicinity of facility.	
Hazard Type: 15 Hazard Description: External fire/explosion Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
None		Incredible	0	A) Barge accident/explosion	Not a credible scenario since none in vicinity of facility.	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 15 Hazard Description: External Event Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
			N/A	A) Sabotage	Excluded due to site security procedures per DOE Order 5480.23.	
Hazard Type: 15 Hazard Description: Natural Phenomena Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
Reportable event to the contaminated worker or public Personnel injury or death Equipment damage Release of silo material Release of pilot plant material	Low	Unlikely	2	A) EBA/DBA High Velocity Winds B) EBA/DBA Earthquake	1. Design has included building evacuation system 2. Design of new facilities to incorporate seismic and natural phenomena hazards as outlined in DOE Order 6430.1A, UCRL-15910, and DOE 5480.28	

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 15 Hazard Description: Severe Natural Phenomena Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
Reportable event to the contaminated worker or public	Low	Extremely Unlikely	1	A) Tornado B) Beyond EBA/DBA High Velocity Winds C) Beyond EBA/DBA Earthquake	1. Design has included building evacuation system	
Personnel injury or death						
Equipment damage						
Release of silo material						
Release of pilot plant material						
Hazard Type: 15 Hazard Description: External Explosion Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
Reportable event to the contaminated worker or public	Moderate	Incredible	0	A) Other facilities in area	1. Nearest facility (CRU1 Support Facility) is at least 200 meters away.	
Personnel injury or death						
Equipment damage						
Release of silo material						
Release of pilot plant material						

OU-4 Integrated Hazard Analysis Evaluation (Continued)

Consequence (Unmitigated)	Consequence Class	Frequency Class	Bin	Cause	Controls/Mitigators	Comment
Hazard Type: 15 Hazard Description: External fire Activities* Associated with the Hazard: 9, 18, 19, 21b, 24, 33, 34						
Reportable event to the contaminated worker or public Personnel injury or death Equipment damage Release of silo material Release of pilot plant material	Moderate	Extremely Unlikely	3	A) Combustible material stored near silos and pilot plant	1. Design has fire protection system 2. Nearest facility (CRU1 Support Facility) is at least 200 meters away	
* The activity numbers are defined in Table 5.						